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THE ROTARY SNOWPLOW FOR CLEARING SIDEWALKS (TEST MODEL), (U)
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Draft Translation 710
March 1979

THE ROTARY SNOWPLOW FOR CLEARING SIDEWALKS

(TEST MODEL)

G. Horikawa

UNITED STATES ARMY
CORPS OF ENGINEERS
COLD REGIONS RESEARCH AND ENGINEERING LABORATORY
HANOVER, NEW HAMPSHIRE, U.S.A.

NOTICE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
Draft Translation 710

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER
(14) CRREL-TRANS-710

4. TITLE (and Subtitle)
(6) THE ROTARY SNOWPLOW FOR CLEARING SIDEWALKS (TEST MODEL),

5. TYPE OF REPORT & PERIOD COVERED
Translation

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
(10) Go Horikawa

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
(12) 25p.

11. CONTROLLING OFFICE NAME AND ADDRESS
U.S. Army Cold Regions Research and Engineering Laboratory
Hanover, New Hampshire

12. REPORT DATE
(11) Mar[redacted]79

13. NUMBER OF PAGES
25

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15. SECURITY CLASS. (of this report)
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

ACCESSION for
NTIS White Section
DDC Buff Section
UNANNOUNCED
JUSTIFICATION
BY
DISTRIBUTION/AVAILABILITY CODES
Dist. AVAIL. and/or SPECIAL
A

18. SUPPLEMENTARY NOTES

Translated by Tech Tran Inc., Glen Burnie, Maryland.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Snow
Snowplows
Snow removal

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The design and development of a rotary snowplow for use on sidewalks is described. The vehicle was designed to remove 600 tons/hr of snow at a forward speed of 4 km/hr. It weighs about 6000 kg and is powered by a 130-hp diesel engine. The snow removal equipment consists of a two-stage rotary blower with a screw type auger. Two plows were constructed and tested. Results so far have been unsatisfactory, mainly because the rear end wobbles at full speed and steering becomes difficult. The snow removal capability also did not meet the design figure.

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THE ROTARY SNOWPLOW FOR CLEARING SIDEWALKS (TEST MODEL)*

Go Horikawa

Introduction

Snow is the lot of Hokkaido during the winter, and if we could overcome this, we would have a much better existence. However, at the present we have not come this far.

The preservation of traffic patterns is one prerequisite for life in a snow country and is one of the major considerations of the Bureau. Therefore we have developed various snow removal machines and introduced them into the city. However, almost all of these have been plows for highways, and the only ones for removing snow from sidewalks have been the ones designed for removing snow from highways but which have been shifted onto sidewalks and remove snow there. This is an unsatisfactory situation.

At present, sidewings on large snow removal machinery can be extended for sidewalk snow removal if there are no sidewalk fences. These sidewings can even directly operate on the sidewalks and push the snow outwards, but this creates a problem because no one can guarantee the conditions of the sidewalk.

Another method is to use a small bulldozer for snow removal, but once again this is almost impossible if there are sidewalk fences.

If sidewalks and other paths where people walk are not cleared of snow, it is necessary for the pedestrians to walk in the street. This of course is very dangerous and causes many problems for people.

In order to correct this neglect of sidewalks, development was begun in 1968 on a 40 HP plow and a 20 HP farm tractor to be used for sidewalk snow removal. The results of this experiment were published in Volume 5, No. 43 of the technical journal and indicate that the performance and capabilities are still quite far from those of a real sidewalk snowplow.

It was at this time that we began development of this snowplow carrying a small, yet powerful engine. Not only would it be capable of removing a maximum amount of snow from sidewalks, but it could also be used for removing accumulated snow from the four corners of an intersection and loading snow that must be removed. It is also powerful enough to take care of anything from new snow to packed snow (as long as it is not frozen) because it is equipped with an auger.

Below is the construction and development history of this vehicle.

A. Plans

1. Location to be used -- a sidewalk with a width of 1.5 m.

2. Procedure -- because this vehicle will operate on the sidewalk, it must remove snow between the road and the sidewalk as well and be able to load an eight ton dumptruck.

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*From Engineering Report, vol. 6, no. 46, p. 51-60.

3. Type of snow -- from new snow to packed snow (excluding ice).

4. Snow removal speed -- more than 4 km/hr with new snow (at a snow accumulation height of 0.2 m, snow density of 0.25, and throwing snow a distance of 14 m).

5. Top speed -- 45 km/hr.

6. Maximum outer turning radius -- less than 4 m (determined from values where R is 3.5 to 5 m at the angle of the intersection's four corners).

7. Vehicle safety standards -- the overall length of the vehicle is less than 4.5 m in order to meet safety standards.

8. Maximum quantity of snow removed -- 600 tons/hr (at a snow removal speed of 4 km/hr and throwing the snow the distance of 14 m).

9. Snow removal equipment type -- two-stage (the one-stage type is not satisfactory for packed snow).

The above-mentioned conditions were stipulated so that this vehicle would have good speed and mobility, as well as to ensure speed of snow removal and handling of packed snow.

B. The Amount of Snow Removed

The following conditions were determined in order to compute the amount of snow removed.

If we set the road width at 7.5 m, the sidewalk width at 1.5 m, the height of accumulated snow at 0.2 m, and the density of the snow at 0.15, we find

$$(7.5 \div 2) + 1.5 - 5.25 \text{ m}$$

(the width from the center line).

$$5.25 \times 0.2 = 1.05 \text{ m}^2$$

The snow amount from the snow removal speed becomes

$$1.05 \times 4 \times 10^3 = 4200 \text{ m}^3/\text{hr}.$$

However, when the road snow has been plowed by a snowplow, the density of the snow may increase to 0.25, and this must be taken into consideration. At this time the volume becomes

$$(4200 \times 0.15) \div 0.25 = 2520 \text{ m}^3/\text{hr}.$$

At this time the snow removal height, when the snow removal width is 1.4 m, becomes

$$\{(5.25 \div 1.4) \times 0.2 \times 0.15\} \div 0.25 = 0.45 \text{ m.}$$

The section of snow to be removed has a width of 1.4 m and a height of 0.45 m. If the snow density is 0.25 and the snow removal speed is 4 km/hr, we obtain a snow removal amount of

$$1.4 \times 0.45 \times 0.25 \times 4 \times 10^3 = 630 \text{ t/hr.}$$

C. Auger

1. Section of Snow to be Transported

The machine with an auger was theoretically based on a worm conveyor, the same as a high-speed rotary snowplow.

Figure 1 shows a cross-section of the auger with the ellipse PAB x t.

$$S_1 = \overset{\frown}{PA} \times t$$

$$S_2 = \overset{\frown}{AB} \times t$$

$$\cos\theta = \frac{D_1 - 2h}{D_1}$$

$$S_1 = \frac{\pi}{4}(D_1^2 - D_2^2) \cdot \frac{\theta}{360}$$

$$S_2 = \frac{\pi}{4}(D_1^2 - D_2^2) \cdot \frac{1}{4}$$

The section of snow to be transported S is

$$S = S_1 + S_2 = \frac{\pi}{4}(D_1^2 - D_2^2) \cdot \left(\frac{\theta}{360} + \frac{1}{4}\right) \cdots\cdots\cdots (m^2)$$

Here the auger outer diameter D_1 is 0.85 m and the inner diameter D_2 is 0.6 m. The snow removal height h was previously calculated as 0.45 m, and from this calculation we find

$$\cos\theta = \frac{0.85 - (2 \times 0.45)}{0.85} = -0.0588 \rightarrow 93^\circ$$

$$S = \frac{3.14}{4}(0.85^2 - 0.6^2) \cdot \left(\frac{93}{360} + \frac{1}{4}\right)$$

$$= 0.144 \text{ m}^2$$

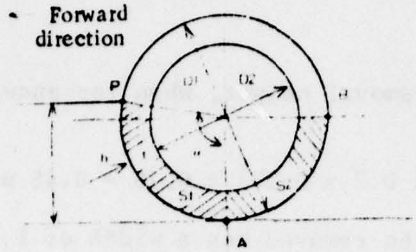


Figure 1. Auger Cross-Section.

2. Transport Speed

With a design snow removal speed of 4 km/hr, we determined the number of auger revolutions to be 5 m/sec with a relative speed between the auger speed and the snow removal speed.

$$V_o = V_c + V_s \text{........(m/sec)}$$

V_o = auger speed

V_c = design snow removal speed -- 4 km/hr

V_s = relative speed -- 5 m/sec.

$$V_o = (4 \times 10^3) \div 3.600 \doteq 1.2 \text{ m/s}$$
$$V_o = 1.2 + 5 = 6.2 \text{ m/s}$$

The auger rpm N_o at this time becomes

$$N_o = \frac{60 \cdot V_o}{\pi D_1} \text{..........................(r.p.m)}$$

$$N_o = \frac{60 \times 6.2}{3.14 \times 0.35} \doteq 140 \text{ r.p.m}$$

3. Pushing Speed

$$V_y = \frac{P \cdot N_o}{60} \text{.....(m/sec)}$$

V_y = pushing speed

P = auger switch -- 1.36 m.

$$V_y = \frac{1.36 \times 140}{60} \doteq 3.17 \text{m}$$

4. Auger Transport Capacity

$$Q_o = S \cdot V_y \cdot 3.600 \times 2 \cdot \varphi_o \cdots\cdots\cdots (m^3/h)$$

Q_o = auger transport capacity

$_o$ = auger transport rate -- 0.8.

$$Q_o = 1.44 \times 3.17 \times 3{,}600 \times 2 \times 0.8$$
$$= 2{,}629\ m^3/h$$

This value is satisfactory because it is even larger than the proposed quantity of snow removed of 2520 m^3/hr.

D. Blower

1. Number of Blower Revolutions

The number of blower revolutions changes depending on the distance that the snow is thrown and the blower diameter. Setting the distance the snow is thrown at 14 m in first gear and 25 m in second gear, and with a blower diameter of 0.85 m, we have the following computation:

$$N_b = \frac{60}{\pi D_b} \cdot \sqrt{\frac{g \cdot l}{\eta}} \cdots\cdots\cdots (r.p.m)$$

N_b = blower revolutions

D_b = blower outer diameter

g = acceleration of gravity -- 9.8 m/sec

l = distance snow is thrown

η = efficiency of snow thrown -- 0.7.

The number of revolutions when the distance the snow is thrown is 14 m becomes according to the above formula

$$N_{b1} = \frac{60}{3.14 \times 0.85} \times \sqrt{\frac{9.8 \times 14}{0.7}} \doteq 315\ r.p.m$$

When the distance thrown is 25 m, the formula becomes

$$N_{b2} = \frac{60}{3.14 \times 0.85} \times \sqrt{\frac{9.8 \times 25}{0.7}} \doteq 420\ r.p.m$$

2. Blower Capacity

The blower capacity is computed as follows from the blower diameter and the auger load capacity.

$$Q_b = A_b \cdot t_b - Ai \quad \cdots\cdots\cdots\cdots \quad (1)$$

$$Q_b = \frac{Q_o \cdot \varepsilon}{N_b \cdot 60 \cdot \xi} \quad \cdots\cdots\cdots\cdots \quad (2)$$

Q_b = blower capacity

A_b = blower area

t_b = blower depth

Ai = blower blade and rotor capacity -- 0.01 m^3

Q_o = auger load capacity -- 2520 m^3

ε = density change rate -- 1.2

ξ = blower capacity efficiency -- 0.8

N_b = *blower revolutions* -- 315 rpm.

From formulas (1) and (2) we obtain

$$t_b = \frac{Q_o \cdot \varepsilon}{A_b \cdot N_b \cdot \xi \cdot 60} + \frac{Ai}{A_b} \cdots\cdots\cdots (m)$$

$$t_b = \frac{2{,}520 \times \frac{1}{1.2}}{\frac{3.14}{4} \times 0.85^2 \times 315 \times 0.8 \times 60} + \frac{0.01}{\frac{3.14}{4} \times 0.85^2} \doteq 0.27\,m$$

E. Necessary Power

There are various ways to measure the snow removal power, but here we shall use the formula developed by Mr. Ei Yamasaki of the Mitsubishi Heavy Industries Tokyo vehicle construction plant.

1. Auger Power

$$W_1 = \left\{0.0133 + 0.042\frac{\mu}{P_1}\left(d_1 - 40\frac{V_1}{n_1}\right)\cos^2\theta + 0.0133\,\mu \sin\theta \cos\theta\right\} K_1 f Q \cdots\cdots (HP)$$

$$\tan\theta = \frac{V_1 \cdot 60}{P_1 \cdot n_1}$$

W_1 = auger horsepower

P_1 = auger pitch -- 1.36 m

μ = friction resistance -- 0.1

d_1 = auger diameter -- 0.85 m

n_1 = number of auger revolutions -- 315 rpm

V_1 = snow removal speed -- 1.2 m/sec

K_1 = coefficient determined from the auger shape -- 0.9

f = snow compression resistance -- 2600 kg/m^2

Q = amount of snow removed -- 0.7 m^3/sec.

$$\tan\theta = \frac{1.2\times 60}{1.36\times 315} \fallingdotseq 0.168 \cdots\cdots\cdots\cdots 9°30'$$

$$W_1 = \left\{0.0133+0.042\frac{0.1}{1.36}\left(0.85-40\frac{1.2}{315}\right)\right.$$
$$\left. 0.986^2+0.0133\times 0.1\times 0.165\times 0.986\right\}$$
$$0.9\times 2{,}600\times 0.7 \fallingdotseq 26 \text{ HP}$$

2. Blower Power

$$W_2 = (0.00068+0.002\,\mu)K_2\rho Q V_2^2 \cdots \text{(HP)}$$

W_2 = blower horsepower

K_2 = coefficient -- 1

V_2 = blower speed -- 14 m/sec

ρ = snow density -- 250 kg/m^3

$$W_2 = (0.00068+0.002\times 0.1)\,1\times 250$$
$$\times 0.7\times 14^2 \fallingdotseq 31 \text{ PS}$$

3. Vehicle Power

$$P_c = \frac{V}{75\times 3.6}(R_1+R_2+R_3+R_4)\cdots\cdots \text{(HP)}$$

P_c = vehicle horsepower

V = snow removal speed (4 km/hr)

R_1 = roll resistance

R_2 = air resistance

R_3 = slope resistance

R_4 = front area resistance.

Here the air resistance has been omitted because the snow removal speed was low, and the slope resistance was also omitted because the test site was on level ground.

$$R_1 = \varphi_1 \cdot G$$
$$R_4 = \varphi_4 \cdot A$$

$_1$ = roll resistance coefficient -- 0.8

$_4$ = comparative front area resistance -- 217.4 kg/cm^2

G = snow removal vehicle, total weight -- 6120 kg

A = snow removal area -- 0.63 m^2.

$$R_1 = 0.08 \times 6,120 = 489.6 \text{ kg}$$
$$R_4 = 217.4 \times 0.63 = 136.96 \text{ kg}$$
$$P_c = \frac{4}{75 \times 3.6}(489.6 + 136.96) \doteqdot 9.3 \text{ HP}$$

4. Total Horsepower

Because the transmission efficiency is not added with the auger, blower and vehicle power, in order to obtain the engine horsepower we added 0.8 as the snow removal power transmission efficiency and 0.8 as the skid power. From this we obtained

$$(26 + 31) \div (0.8 \times 0.8) = 89 \text{ HP}.$$

On the other hand the transmission efficiency of the vehicle power is that of the oil pressure mechanical type, and therefore we set the entire transmission efficiency at 0.6 and obtained

$$9.3 \div 0.6 = 15.5 \text{ HP}$$

This gives a total horsepower of

$$89 + 15.5 = 104.5 \text{ HP}.$$

However, because approximately 10 HP are needed for auxiliary power for the power steering pump and the snow removal control pump, we added this and obtained a final engine horsepower of 114.5 HP.

F. Structural Description

The main problem with designing this rotary snow removal plow was not only taking into consideration the surface of the sidewalk, but also to make the turning radius smaller and more compact. We based the turning radius on a center pivot type steering method. To make the vehicle more compact and shorten the overall length and width of the vehicle, we arranged the machinery to be more packed and shortened the length as well as open areas of the vehicle.

Up to now rotary snowplows have had a large front overhang in their construction, and this has caused pitching and steering problems. On this vehicle we have reduced the dimensions by raising the chain case rear section for the auger. In order to shorten the axle base, we shortened the front overhang by positioning the bevel gearbox on the side of the blower case. The area in front and in back of the axles has also been reduced.

Figure 2 illustrates the structure. This snow removal vehicle has two-stage rotary snowplow equipment capable of cutting packed snow in front. The engine for running the vehicle and for the snow removal equipment is in the rear.

The power sequence is as follows: engine → main clutch → propellor shaft → power distributor. From this the power is taken off for running the vehicle and for snow removal. The power sequence for running the vehicle is as follows: oil pressure pump → oil pressure motor → transmission for running → propellor shaft → intermediate bearing → propellor shaft → → transmission. This is also divided into front and rear. The front system is as follows: propellor shaft → front axle differential → front wheels.

The rear system is as follows: propellor shaft → rear wheel differential → rear wheels.

Snow removal power is divided into auger power and blower power through the power distributor. The auger system is as follows: propellor shaft → → level gearbox → bevel gearbox → chain transmission → safety equipment → → auger.

The blower system is: propellor shaft → safety equipment → level gearbox → blower.

The special length of this vehicle for handling packed snow allows the snow removal equipment to tip back and tilt.

Among the four parallel links, the upper two links are oil pressure cylinders, and as these expand or contract the auger tilts forward and touches the packed snow. This allows it to cut the snow more easily.

The tilt is developed by round bushings on the edges of the above- -mentioned links and oil pressure cylinders. The machine can tilt to the right or left with the aid of two oil pressure cylinders which operate

independently and lift the auger. (Note: because the round bushings are attached at eight points, sideways vibration can occur, but this is damped by horizontal rods.)

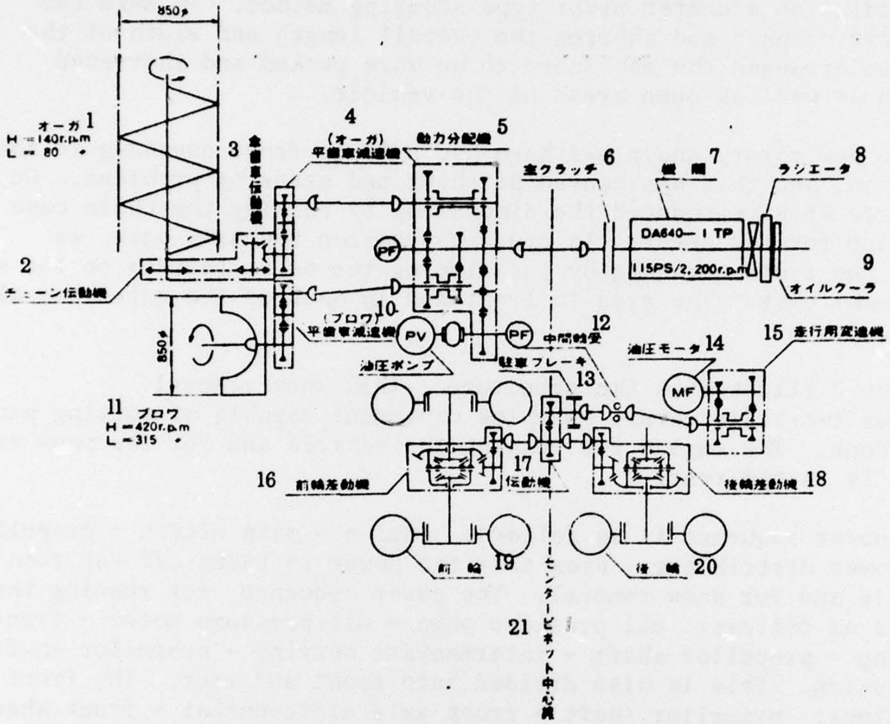
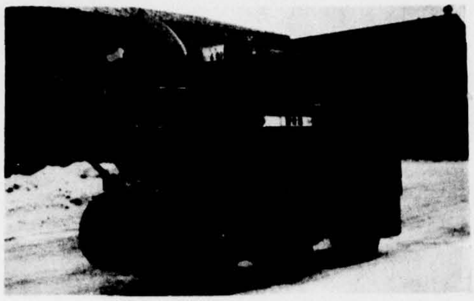


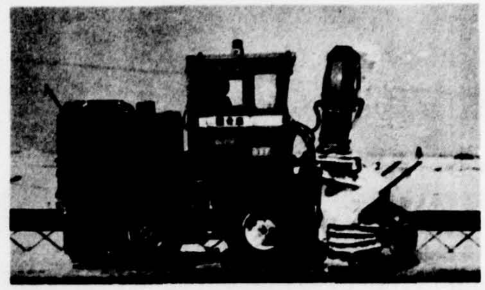
Figure 2. Power Transmission Diagram. 1, Auger; 2, chain transmission; 3, bevel gear transmission; 4, (auger) level gear governor; 5, power distributor; 6, main clutch; 7, engine; 8, radiator; 9, oil cooler; 10, (blower) level gear governor; 11, oil pressure pump; 12, intermediate bearing; 13, parking brake; 14, oil pressure motor; 15, vehicle gearbox; 16, front wheel differential; 17, transmission; 18, rear wheel differential; 19, front wheel; 20, rear wheel; 21, center pivot main line.

Some other features of this vehicle which we consider unusual are the use of shock absorbers for suspension to give a comfortable ride and compensate for extreme pitching. The meshing of gears can be done freely because the auger snow removal equipment and the blower gears are attached separately on the power transmission. This is effective for this kind of rotary snowplow, the engine of which has such a small output.

The above is a summary of the sidewalk rotary snowplow. For your consideration we now present the main specifications and a four-way view in Figure 3, as well as a picture of the entire vehicle in photograph No. 1 and the vehicle in operation in photograph No. 2.



Photograph 1. The Entire Vehicle.



Photograph 2. The Vehicle in Operation.

Major Specifications

1. Type

MR-12

2. Performance

Maximum quality of snow removal 600 t/hr

Snow density	0.25 t/m^3	at
Distance snow is thrown	14 m	
Snow removal speed	4 km/hr	
Snow removal height	0.45 m	

Maximum snow removal width 1460 mm

Snow removal machinery height above surface 1010 mm

Distance snow is thrown

1st gear	14 m
2nd gear	25 m

Vehicle speed (forward and reverse)

1st gear	0-10 km/hr
2nd gear	0-45 km/hr

Minimum turning radius

Outer clearance
Minimum turning radius (auger tip section) 3685 mm
Outer wheel minimum turning radius (front and rear tires) 2960 mm
Inner clearance
Minimum turning radius (fender section) 1860 mm

Climbing performance 26°

Maximum safe incline angle 31°

3. Major Specifications

Overall length (vehicle length)	4524 cm
Overall width (snow removal equipment width)	1460 mm
Overall height (to the tip of the yellow flashing light)	2750 mm
Underside clearance (to the lower surface of the front and rear differential case)	250 mm

Weight

Total weight (including one operator)	6120 kg
Front axle	3245 kg
Rear axle	2875 kg
Vehicle weight	4910 kg
Snow removal equipment weight	1210 kg

Operator 1

4. Parts Description

4-1. The Vehicle Itself

Type: center pivot type all-wheel oil pressure operation

Major Specifications

Overall length (from the front tip of the frame to the rear bumper)	3160 mm
Overall width (fender width)	1260 mm
Overall height (to the tip of the yellow flashing light)	2750 mm
Underside clearance (to the lower surface of the front and rear wheel differential cases)	250 mm
Axle length	1550 mm
Wheel length (both front and rear wheels)	1020 mm

Engine

Name: Iseuzu AA 640-ITP type diesel engine

Type: four-cycle water-cooled overhead valve direct drive turbo-charged engine

Cylinder number: inner diameter x stroke 6-102 mm x 130 mm

Overall stroke capacity: 6373 cc

Compression ratio: 22:1

Performance

Fixed revolutions	2200 rpm
Continuous fixed output	115 HP
Maximum output during operation	130 HP
Maximum torque	46 kg-m (1600 rpm)
Fuel consumption rate	198 gr/HP.hr

Fuel injection pump Bosch type

Governor -- centrifugal all-speed control

Lubrication system

Lubrication method -- forced circulation
Filter system -- full-flow type
Coolant -- water

Air filter -- cyclone oil base

Coolant type -- output pressurizer, centrifugal pump circulation

Supercharger XM-51

Electrical system -- AC 24 V - 350 W

Starter -- 24 V - 3.7 kW

Battery -- 12 V-120 AH, 2 grounded

Main clutch

Type: dry, single-plate

Power distributor

Power transmission for vehicle

Type: level gear engaged during normal operation

Gearbox ratio: 1.0

Gears for snow removal

Auger

Type: level gearbox two variable speeds

Gear ratio (1st gear) 1.85
(2nd gear) 1.18

Blower

Type: level gearbox two variable speeds during operation

Gear ratio (1st gear) 2.23
(2nd gear) 1.69

Oil pressure pump

Name: Daikin Sandstrand 21 PV

Variable capacity piston pump -- 1

Angle of incline -- 0-±18°

Output -- 125 l/min (200 kg/cm^2, 2200 rpm)

Normal pressure -- 210 kg/cm^2

Maximum instantaneous pressure -- 700 kg/cm^2

Number of revolutions -- 2200 rpm fixed engine rpm

Equipment location and operational procedure -- shaft operation in front of the power distributor

Oil pressure motor

Name: Daikin Sandstrand 21 MF

Type: fixed capacity piston motor -- 1

Set incline angle -- 18°

Torque -- 16.7 kg-m (210 kg/cm^2)

Normal pressure -- 210 kg/cm^2

Set relief pressure -- 350 kg/cm^2

Number of revolutions -- 2153 rpm fixed engine rpm

Equipment location and running operation -- attached directly to the input shaft of the governor

Governor

Type: level gearbox double gear

Gear ratio (1st gear) 2.31
(2nd gear) 0.51

Transmission

Type: level gearbox normal mesh

Gearbox ratio -- 1.176

Operational procedure

Type: 4 x 4 all-wheel operation

Operation

Front axle all-floating

Rear axle all-floating

Differential

Type: level gearbox, bevel gearbox two-speed governor

Gear ratio (level gearbox) -- 2.25

Gearbox ratio (bevel gearbox) -- 5.833

Suspension

Front axle -- half-oval heavy-duty shock absorbers

Rear axle -- " " " " " "

Brakes

Main brakes -- oil pressure type inner tension all-wheel brakes (vacuum double-power)

Parking brakes -- mechanical outer tension axle brake

Frame

Type: steel housing single-frame

Steering

Type: center pivot type (oil pressure booster)

Handle location, shape -- center, round wheel

Tires

Type: off-road

Size: 750-20, 10 PR (all front and rear tires)

Operator's cab

Construction -- all-enclosed steel construction right and left two-door type

Seat -- for one person

Oil pressure equipment

Oil pressure pump (for operation)

Type: two-gear single pumps

Output: 17.3 l/min (2200 rpm)

Number of revolutions -- 2200 rpm (fixed engine rpm)

Equipment location and operational procedure -- directly connected to the power distributor input shaft and the oil pressure pump shaft

Set relief valve pressure -- 140 kg/cm^2

Oil pressure pump (for steering)

Type: one-gear single pump

Output -- 19.5 l/min (1500 rpm)

Number of revolutions -- 1500 rpm (fixed engine rpm)

Equipment location and operational procedure -- V belt operation from engine crank pulley section

Valve unit set pressure -- 70 kg/cm^2

Operation valves

Type: lever operation

Operating position (for lifting the snow removal equipment) up, center, lower, floating -- 2

Operating position (for rotating the lower case) left, center, right -- 1

Operating position (tipping rearward) front, center, back -- 1

Operating position (for rotating the loading chute) left, center, right -- 1

Operating position (for loading cap) upper, center, lower -- 1

Towing equipment

Type: fixed pintle type

Capacity: 2040 kg

Center height: 840 mm

Water, oil volume

Water coolant --	14 l
Fuel tank --	150 l
Engine lubricating oil --	12 l
Power distributor --	6 l
Governor for operation --	6 l
Transmission --	4 l
Differential --	5 l
Operational oil --	25 l
Operational oil for oil pressure equipment --	15 l

4-2. Snow Removal Equipment

Type: two-stage rotary

Specifications

Overall length (from the tip of the auger to the rear of the level gearbox governor)	1370 mm
Overall width	1460 mm
Overall height (to the blade from the top of the loading chute)	2450 mm
Weight	1210 kg

Operational equipment

Auger

Type: screw type

Width x outer diameter -- number 850 mm x 1240 mm -- 1

Screw number -- 1

Safety equipment -- Sharpin type (2)

Number of revolutions (fixed engine rpm)

1st gear 89 rpm
2nd gear 140 rpm

Blower

Type: rotary type

Blower number -- 1

Blade outer diameter x blade depth -- 830 mm x 280 mm

Number of blades -- 5

Safety equipment -- Sharpin type (2)

Number of revolutions (fixed engine rpm)

1st gear 315 rpm
2nd gear 433 rpm

Equipment for lifting the snow removal equipment

Type: four parallel lengths maintained at four points

Operational type: oil pressure

Blade maximum lift --300 mm

Blade maximum cutting depth -- 50 mm

Oil pressure cylinders (for lifting the snow removal equipment)

Type: modified system

Cylinder diameter x stroke -- number -- 60 mm x 350 mm -- 2

Blower case

Type: release angle, variable

Operational type: oil pressure

Release angle adjustment range -- left, right 45° each

Oil pressure cylinder (for rotating blower case)

Type: modified system

Cylinder diameter x stroke -- number -- 45 mm x 300 mm -- 1

Tip back

Type: snow removal equipment front inclining system

Operational type: oil pressure

Maximum forward inclination angle -- 7°

Oil pressure cylinders (for tipping rearward)

Type: modified system

Cylinder diameter x stroke -- number 50 mm x 85 mm -- 2

Loading chute

Type: directional release turning

Operational type: oil pressure motor system

Chute rotation angle -- 220°

Minimum snow throwing distance -- 2 m

Oil pressure motor (for chute rotation)

Type: gear motor

Number: 1

Loading chute cap

Type: release angle variable

Operational test: oil pressure

Cap adjustable angle range: 80°

Oil pressure cylinder (for chute cap)

Type: modified system

Cylinder diameter x stroke -- number 45 mm x 280 mm -- 1

Shoe

Type: sled type

Adjustment procedure: manual

Adjustment: from the blade upwards 30 mm, downwards 10 mm

Number: 2 (1 on the right and 1 on the left)

Power transmission system

Level gearbox governor (for auger)

Type: level gearbox normal engagement

Gear ratio: 3.03

Bevel gearbox governor (for auger)

Type: bevel gearbox normal engagement

Gearbox ratio -- 2.56

Chain transmission

Type: single-row roller chain system

Gear ratio: 1.71

Level gearbox governor (for the blower)

Type: level gearbox normal engagement

Gear ratio: 3.0

Oil capacity

Level gearbox governor: 4.5 *l* (for auger)

Bevel gearbox governor: 3.0 *l* (for auger)

Chain transmission: 6 kg (grease)

Level gearbox governor: 2.0 *l* (for blower)

4-3. Operating Equipment

Levers and pedals

Steering wheel (with a horn button attached)	-- 1
Clutch pedal	-- 1
Brake pedal	-- 1
Stepless accelerator	-- 1
Forward and backward lever (with a reverse light switch)	-- 1
Parking brake lever	-- 1
Choke lever	-- 1
Engine stop lever	-- 1
Gearshift lever for vehicle	-- 1
Gearshift lever for snow removal equipment	-- 2
Lever for lifting snow removal equipment	-- 2
Blower case rotation lever	-- 1
Tip back lever	-- 1
Loading chute rotation lever	-- 1
Loading chute cap lever	-- 1

Gauges and switches

Oil pressure warning light (for engine)	-- 1
Water temperature warning light (for engine)	-- 1

Voltage warning light (for engine)	-- 1
Oil temperature warning light (for oil pressure pump and motor for vehicle)	-- 1
rpm gauge (service meter attached)	-- 1
Speedometer (tachograph, seven-day)	-- 1
Fuel gauge (see-through type)	-- 1
Battery switch	-- 1
Starter switch	-- 1
Light switch	-- 1
Turn signal switch (dimmer switch attached)	-- 1
Dome light switch	-- 1
Yellow flashing light switch	-- 1
Wiper switch	-- 1

Lighting equipment and other equipment

Headlights	-- 2
High-beams	-- 2
Front and side turn signal lights (for parking lights)	-- 2
Taillights and brake lights and turn signals (for parking lights)	-- 2
Back-up lights	-- 1
License plate light	-- 1
Dashboard light	-- 1
Dome light	-- 1
Yellow flashing light (sealed beam)	-- 1
Rearview mirror	-- 2
Room mirror	-- 1
Rear underside mirror	-- 1
Horn (electric)	-- 1

5. Miscellaneous

Cab heater (water temperature type generating more than 2500 kcal/hr, with defroster attached)	-- 1
Wipers (electric torque with more than 55 kg-cm)	-- 1
Tire chains	-- 1 set
Floor mats (for insulation)	-- 1
Fire extinguishers (ABC type fire extinguisher, with a fuel capacity of 1.5 kg, meeting Japanese Standards)	-- 1
Signal flare (with more than 300 candlewatt with enough fuel for more than 5 minutes)	-- 1
Automobile signal light	-- 1
Hand flag (red)	-- 1

Conclusion

We constructed two of these rotary snowplows, and they are currently located at the Sapporo and Asahikawa Proving Grounds. So far the operational results have not been very satisfactory.

The main reason for this is the fact that the rear-end wobbles at high speed. Steering becomes difficult when the vehicle swings heavily to the side.

Tune-ups are also very difficult because the vehicle is constructed so compactly. There have been problems with the hoses and pipes bending and breaking. Another problem is the fact that there is a greater rise than anticipated between the roads and sidewalks in cases where this vehicle must climb from the roads to the sidewalk. Even though there is no great danger of overturning, when the vehicle leans heavily as it changes from road to sidewalk snow removal, it is still not living up to its expectations.

This year it is also necessary to correct the fact that the snow removal capability is also not as high as was anticipated.

However, despite the above-mentioned problems, this is still the first machine of its type. Naturally there have been many problems, but we believe that it has potential as a sidewalk snow removing plow. We are working very hard this year to correct the above-mentioned deficiencies.

The main aspects of the improvement are to make the vehicle safer, to increase its tread width from 1020 mm to 1160 mm, to eliminate the rear end shaking and operational deficiencies which cause power steering failures, and to greatly improve the power steering capacity itself.

We believe that this vehicle can be used efficiently with a few minor improvements. Besides checking this year's operational conditions, we are convinced of the advisability of using this type of snow removal vehicle for sidewalk snow removal.

Here we would like to extend our thanks to all the people who have helped build this rotary snowplow.

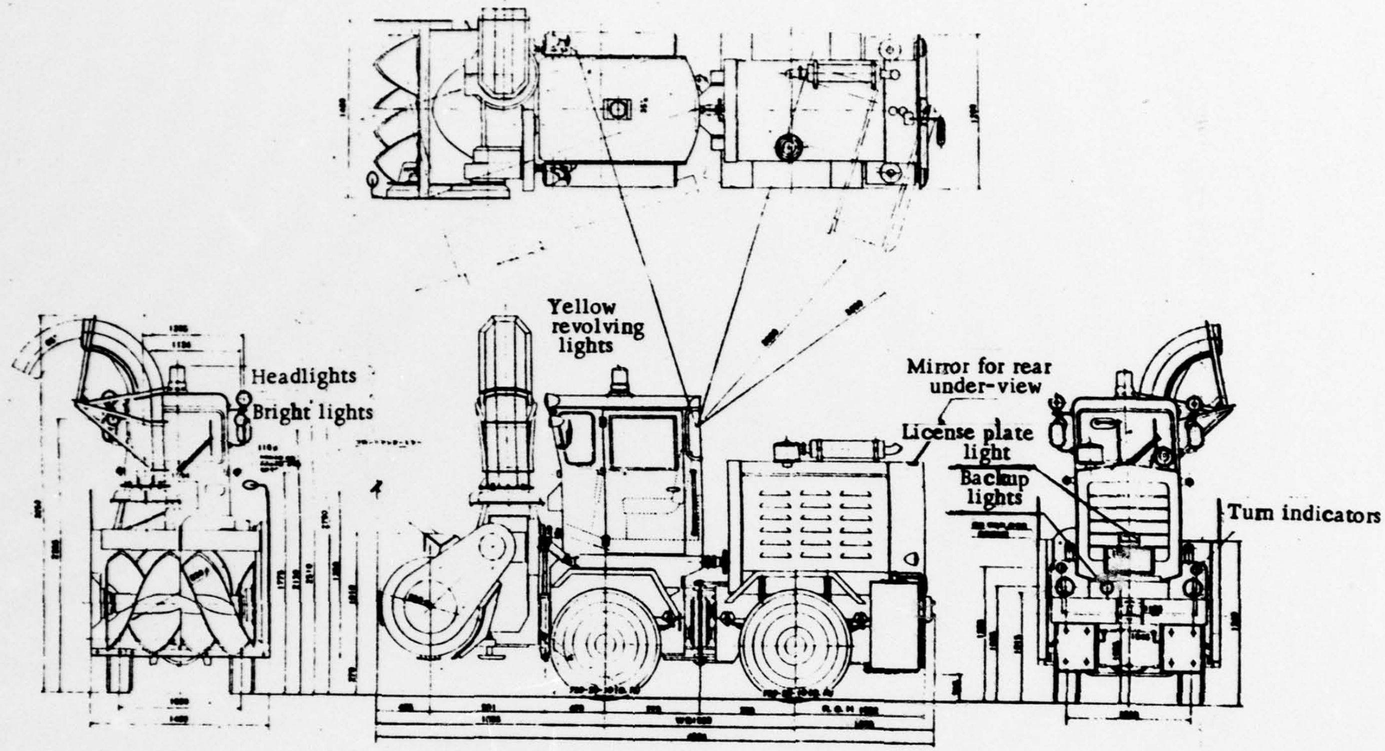


Figure 3. Four Views of the Snow Plan.